ICESat

Ice, Cloud and land Elevation Satellite

ICESat URL
icesat.gsfc.nasa.gov/

Key ICESat Facts

Orbit:
Type: Near polar, low-Earth orbit
Altitude: ~600 km
Inclination: 94°
Period: ~97 minutes
Repeat Cycle: 91 days with ~33 days subcycle

Dimensions: Approximately 2.2 m × 1.0 m × 1.5 m, solar panel area is ~8 m^2

Mass: ~950 kg total

Power: ~330 W (GLAS)

Downlink: X-Band and S-Band radio-frequency channels

Design Life: 3 years

Summary

ICESat provides primarily ice sheet and sea ice altimetry products with secondary products being cloud/aerosol and land/vegetation data. In particular, the mission determines variations of ice sheet elevation through time over Greenland and Antarctica, altitude and thickness of clouds and aerosol layers, vegetation, land topography, and ocean surface and sea ice altimetry.

Instrument

- Geoscience Laser Altimeter System (GLAS)

Points of Contact

- *ICESat Project Scientist:* H. Jay Zwally, NASA Goddard Space Flight Center
- *ICESat Science Team Leader:* Bob E. Schutz, University of Texas-Austin

Other Key Personnel

- *ICESat Program Scientist:* Craig Dobson, NASA Headquarters
- *ICESat Program Executive:* Lou Schuster, NASA Headquarters

Mission Type

Earth Observing System (EOS) Systematic Measurements

Launch

- *Date and Location:* January 12, 2003, shared launch with the Cosmic Hot Interstellar Plasma Spectrometer (CHIPS), from Vandenberg Air Force Base, California
- *Vehicle:* Delta II rocket

Relevant Science Focus Areas

(see NASA's Earth Science Program section)

- Climate Variability and Change
- Earth Surface and Interior
- Water and Energy Cycles

Related Applications

(see Applied Sciences Program section)

- Air Quality
- Carbon Management
- Coastal Management
- Ecological Forecasting
- Water Management

ICESat Science Goals

- Provide repeated, precision, polar ice sheet elevations through time for improved mass-balance measurements
- Provide atmosphere-cloud heights and aerosol distribution data
- Provide land topography and vegetation cover data

ICESat Mission Background

GLAS is an advanced, high-precision, solid-state, neodymium:yttrium-aluminum-garnet (Nd:YAG) laser altimeter. It has three lasers to improve the reliability for meeting its planned multi-year mission, but only one laser is operational at any given time. GLAS uses integral star trackers and gyros for determination of precise laser orientation and GPS for precise position determination; this is augmented by ground-based-satellite laser ranging. Data from the components of GLAS are combined to provide Earth elevation data with a precision of 10 cm or better per laser pulse.

The mission's science objectives are repeated, precision, ice sheet elevation data that will enable improved mass-balance estimates for Greenland and Antarctica. In addition, as the GLAS instrument produces 532-nm (visible) as well as 1064-nm (near-infrared) wavelength pulses, it provides cloud and aerosol information that is not available from passive sensors, especially of the layering structure through the atmosphere. The temporal and spatial extent of clouds common to polar areas that may impact the ice sheet measurements is also being determined. Finally, the third science objective of the ICESat mission, collection of land-topography data, is being achieved by processing the continuously operating laser-altimeter data throughout its global orbit.

ICESat began its science mission on February 20, 2003. It is now orbiting with the GLAS instrument operating for specific periods.

GLAS

Geoscience Laser Altimeter System

GLAS has three lasers, with only one laser operating at any given time. Precision orbital and pointing knowledge is obtained via redundant GPS units, a gyro system, a laser reference system, and instrument- and spacecraft-mounted star trackers, supported by ground-based laser ranging. GLAS includes the Stellar Reference System, which consists of a charge-coupled device (CCD) camera system to determine the direction of the laser beam with respect to the stars and also with respect to the GLAS optical bench.

The ICESat mission measures ice sheet topography and associated temporal changes, cloud and atmospheric properties, and along-track topography over land and water. For ice sheet applications, the laser altimeter effectively measures the distance from the spacecraft to the ice sheet, to a precision of better than 10 cm with a laser surface-spot size of ~70 m every ~170 m. The distance measurement, coupled with knowledge of the radial orbit position and the direction of the laser beam in space, enables the precise determination of surface topography. Characteristics of the return pulse are used to determine surface roughness. Changes in ice sheet thickness even of a few tens of centimeters provide information needed for improved ice sheet mass balance estimates and support prediction analyses of cryospheric response to climatic changes. The ice sheet mass balance and contribution to sea-level change will also be determined over the mission lifetime. The accuracy of height determinations over land is assessed using ground slope and roughness data. Along-track cloud- and aerosol-height distributions are determined with a vertical resolution of ~75 m. The horizontal resolution of ICESat's cloud data varies from 175 m for dense clouds to 50 km for the thinnest aerosol structure and planetary boundary layer height. Unambiguous measurements of cloud height and the vertical structure of thin clouds support studies on

Key GLAS Facts

Heritage: MOLA

Instrument Type: A three-laser system, with a single laser operating at any given time

Scan Type: Nadir Viewing

Dimensions: Telescope diameter is 1 m, instrument height is ~175 cm

Mass: 300 kg

Power: 330 W average

Data Rate: ~450 kbps

Specifications:

	Surface	Atmosphere
Wavelengths	1064 nm	532 nm
Laser Pulse Energy	74 mJ	30 mJ
Laser Pulse Rate	40 Hz	40 Hz
Laser Pulse Width	5 nsec	5 nsec
Telescope Diameter	1.0 m	1.0 m
Receiver FOV	0.5 mrad	0.16 mrad
Receiver Optical Bandwidth	0.8 nm	0.03 nm
Detector Quantum Efficiency	30%	60%
Detection Scheme	Analog	Photon Counting
Vertical Sampling Resolution	0.15 m	75 m
Surface Ranging Accuracy (single pulse)	< 10 cm/pulse	
Laser Pulse Pointing Knowledge	< 2 arcsec	

Uses: Nd:YAG laser with 1.064- and 0.532-μm output

Primary cloud and aerosol data are extracted from the green pulse

Height Measurements: Determined from the round-trip pulse time of the infrared pulse the influence of clouds on radiation balance and climate feedbacks. Polar clouds and haze are detected and sampled with much greater sensitivity, vertical resolution, and accuracy than can be achieved by passive sensors. Planetary boundary layer height is directly and accurately measured for input into surface-flux and air-sea and air-land interaction models. Direct measurements of aerosol vertical profiles contribute to understanding of aerosol-climate effects and aerosol transport.

The GLAS instrument was developed by a NASA GSFC led instrumentation team, and the ICESat spacecraft was supplied by Ball Aerospace. GLAS uses a diode-pumped, Q-switched Nd:YAG laser with energy levels of approximately 75 mJ (1.064 µm) and 35 mJ (0.532 µm). Three lasers are included, but only one laser operates at a time. The pulse repetition rate is 40 pulses/s, and the beam divergence is approximately 0.11 mrad. The echo pulses are collected in a 1-m-diameter telescope. The infrared pulse is used for surface altimetry and some cloud measurements, and the green pulse is primarily used for measurements of thin clouds but is also used for aerosol measurements.

The Stellar Reference System (SRS), which is part of the GLAS instrument, supports determination of the laser-pointing direction in space with a precision of about 1.5 arcsec. SRS consists of several CCD cameras: an Instrument Star Tracker (IST), a Laser Reference System (LRS), and a Laser Profile Array (LPA). SRS is an innovative instrument developed at GSFC. IST obtains 10-Hz images of the star field in the instrument zenith direction with an 8° field of view, and LRS includes a 10-Hz, 0.5° field of view of the stars that overlaps with IST. LRS also captures an image of the transmitted 1064-nm laser pulse and an image of a collimated reference source mounted on IST. LPA also images the transmitted laser pulse, but the imaging is performed at 40 Hz.

GLAS URL

glas.gsfc.nasa.gov/

ICESat References

Algorithm Theoretical Basis Document References available at: www.csr.utexas.edu/glas/atbd.html.

GLAS Science Team: Geoscience Laser Altimeter System GLAS: Science Requirements, Version 2.01, October 1997.

ICESat Brochure available at: icesat.gsfc.nasa.gov/publicoutreach.htm.

Zwally, H. J., B. Schutz, W. Abdalati, J. Abshire, C. Bentley, *et al.*, 2002: ICESat's laser measurements of polar ice, atmosphere, ocean, and land. *J. Geodyn.*, **34**, 405–445.

Key GLAS Facts *(cont.)*

Spatial Resolution: At 40 pulses per second, the centers of 70-m spots are separated in the along-track direction by 170 m for a 600-km altitude orbit; the cross-track resolution is determined by the ground-track repeat cycle and orbit control.

Duty Cycle: 100%

Thermal Control: Radiators, heat pipes, supplemented by heaters

Thermal Operating Range: 20° ± 5° C

Telescope FOV: Nadir only, 375 µrad and 160 µrad (0.532 µm)

Instrument IFOV: ~70 m laser footprint at nadir

Pointing Requirements (platform + instrument):

Control (3σ): 30 arcsec roll, 30 arcsec pitch, 1° yaw.

Post-processed pointing knowledge (1σ): 1.5 arcsec (roll and pitch axes, provided by instrument-mounted star trackers, gyro system, and Stellar Reference System.

Post-processed position requirements: Radial orbit for ice sheet to <5 cm and along-track/cross-track position to <20 cm (to be provided by spacecraft-mounted GPS receiver and SLR array).

Orbit repeat tracks: The ICESat orbit is controlled so that its ground track is maintained within 800 m at the equator of a specified reference (ideal) ground track and to ~100 m over polar ice.

Off-nadir pointing: ICESat enables off-nadir pointing of the laser up to 5° to enable repeat ground tracks at approximately 100 m and to point at targets of opportunity, including calibration targets; in the polar regions, the GLAS laser is always pointed at the reference ground track to support repeat-track analysis.

Reference orbit: ICESat uses two reference ground tracks: an 8-day repeat track and a 91-day repeat track. The 91-day repeat track has an approximately 33-day subcycle, which provides a nearly uniform distribution of tracks with a 30-km separation between tracks in the same direction at the equator.

ICESat Data Products

ICESat data can be accessed at: nsidc.org/data/icesat.

Product Name or Grouping	Processing Level	Coverage	Spatial/Temporal Characteristics
GLAS *Data Set Start Date: February 20, 2002*			
Global Altimetry Data	1A	Global	70 m footprint sampled at 170 m spacing, vertical resolution 3 cm
Global Atmosphere Data	1A	Global	40 km vertical coverage sampled at 170 m spacing, vertical resolution 76 m
Global Engineering Data	1A	Global	Sampled once every 4 seconds
Global Laser Pointing Data	1A	Global	Sampled at 40 Hz and 10 Hz
Global Waveform-based Range Corrections Data	1B	Global	70 m footprint sampled at 170 m spacing, vertical resolution 3 cm
Global Elevation Data	1B	Global	70 m footprint sampled at 170 m spacing, vertical resolution 3 cm
Global Backscatter Data	1B	Global	40 km vertical coverage sampled at 170 m spacing, vertical resolution 76 m
Global Planetary Boundary Layer and Elevated Aerosol Layer Heights	2	Global	40 km vertical coverage sampled at 170 m spacing, vertical resolution 76 m
Global Heights for Multi-layer Clouds	2	Global	40 km vertical coverage sampled at 170 m spacing, vertical resolution 76 m
Global Aerosol Vertical Structure Data	2	Global	40 km vertical coverage sampled at 170 m spacing, vertical resolution 76 m
Global Cloud/Aerosol Optical Depths Data	2	Global	40 km vertical coverage sampled at 170 m spacing, vertical resolution 76 m
Antarctic and Greenland Ice Sheet Altimetry Data	2	Global	70 m footprint sampled at 170 m spacing, vertical resolution 3 cm
Sea Ice Altimetry Data	2	Global	70 m footprint sampled at 170 m spacing, vertical resolution 3 cm
Global Land Surface Altimetry Data	2	Global	70 m footprint sampled at 170 m spacing, vertical resolution 3 cm
Ocean Altimetry Data	2	Global	70 m footprint sampled at 170 m spacing, vertical resolution 3 cm

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